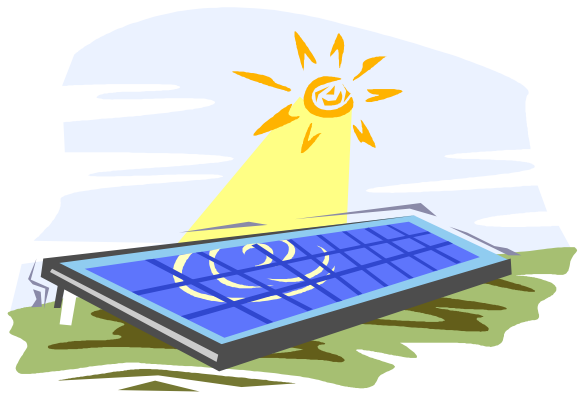
Solar Photovoltaic Systems

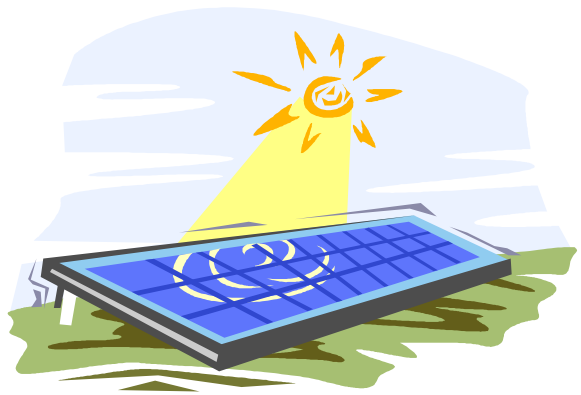
Overview and Standards for Permitting, Installation,
Code Compliance and Inspections

DER Road Show



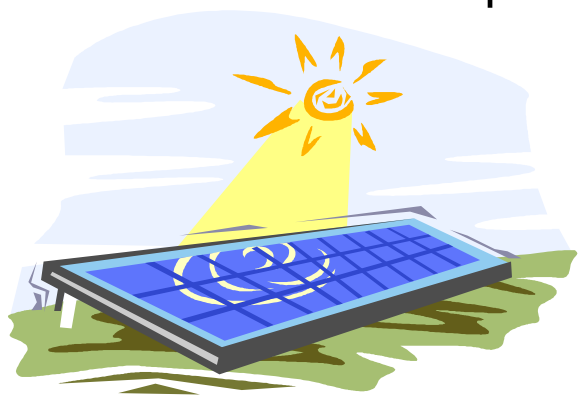
Presentation Overview

- State of the technology overview
- Standards for permitting and inspecting PV installations
- Overview of PV systems and components
- Installation methods
- Utility Interconnection Issues
- PV system inspection checklist
- Reference resources



Background on Photovoltaic Technology

- Commercially available for space program since 1954
- Used on earth since 1970's
- Over 1,600 megawatts of capacity installed
- Over 20,000 buildings in U.S. uses photovoltaic for part or all of its power
- Industry is growing at a 30-40% annual rate - $3.5 billion est in 2002
- A photovoltaic system generates almost as much electricity in Midwest as in Florida
- Midwest availability of electricity from sun is a close match to power demand – daytime and summer



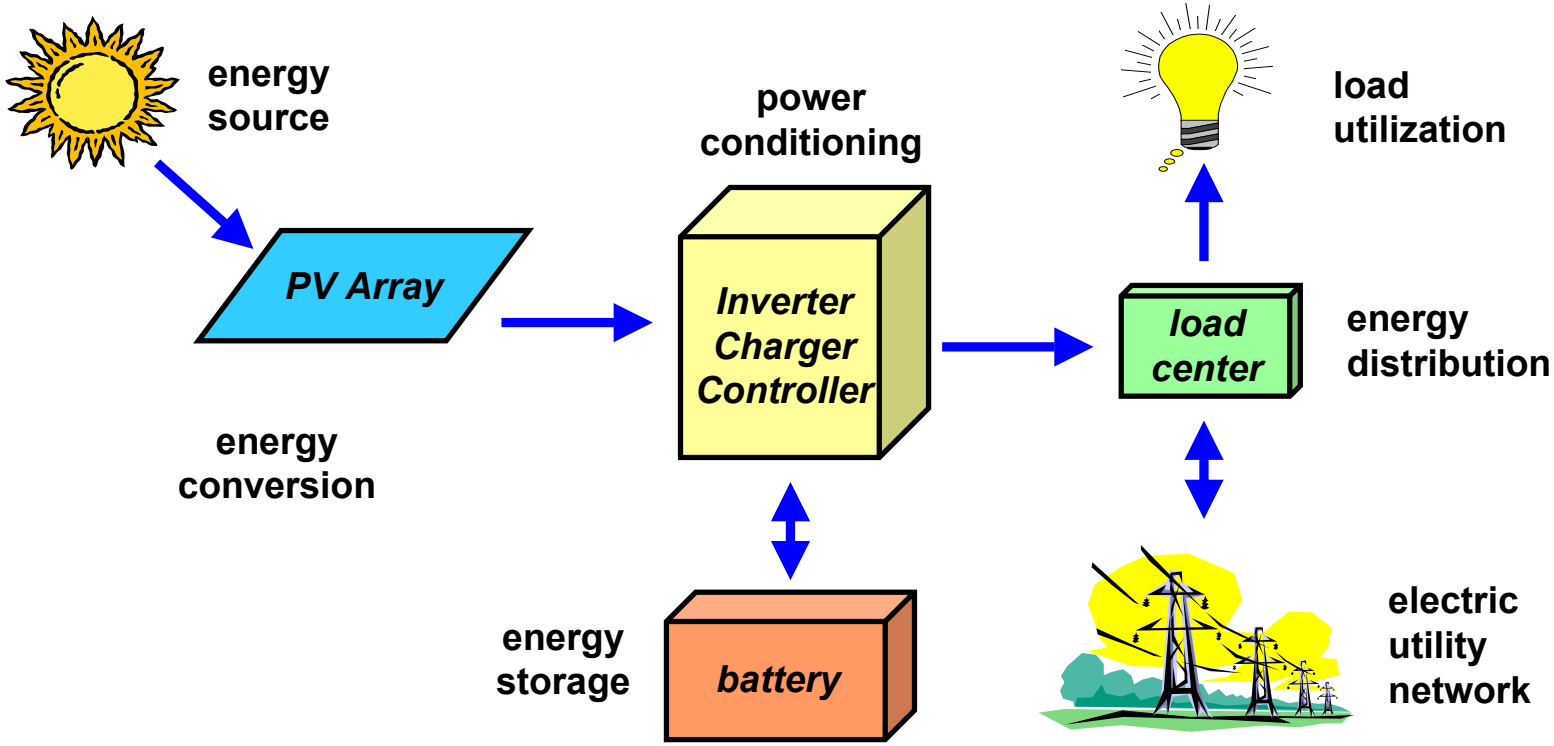
Requirements for Solar Photovoltaic System Installations

- **Permits**
  - Building permits are applied for by contractor or property owner.
  - Plans examiner reviews plans, grants approvals as required.
- **Installation**
  - System is installed by a licensed contractor (or property owner) in a code-compliant manner, in accordance with jurisdictional requirements.
- **Inspections**
  - Installation is inspected by the local building code official and approved.
- **Interconnection**
  - Owner completes interconnection agreement with local utility, including requirements for system design and equipment, inspection certificates, insurance, disconnect provisions and other matters as required.

Example: Who Installs and Inspects PV Systems in Florida

- **Solar Contractor**
  - FS 489 Part I, FAC 61G4
  - Construction Industry Licensing Board:
  - http://www.state.fl.us/dbpr/pro/cilb/cilb_index.shtml
- **Electrical Contractor**
  - FS 489 Part II, FAC 61G6
  - Electrical Contractors' Licensing Board: http://www.state.fl.us/dbpr/pro/elboard/elec_index.shtml
- **General Contractors and others**
  - see restrictions in FS 489 Part I, FAC61G4
- **Property owner**
  - see exemptions and restrictions, FS 489 Part I and Part II
- **Building Code Administrators and Inspectors**
  - FS 468 Part XII, FAC 61G19
  - Building Code Administrators and Inspectors Board:
  - http://www.state.fl.us/dbpr/pro/buildc/bc_index.shtml

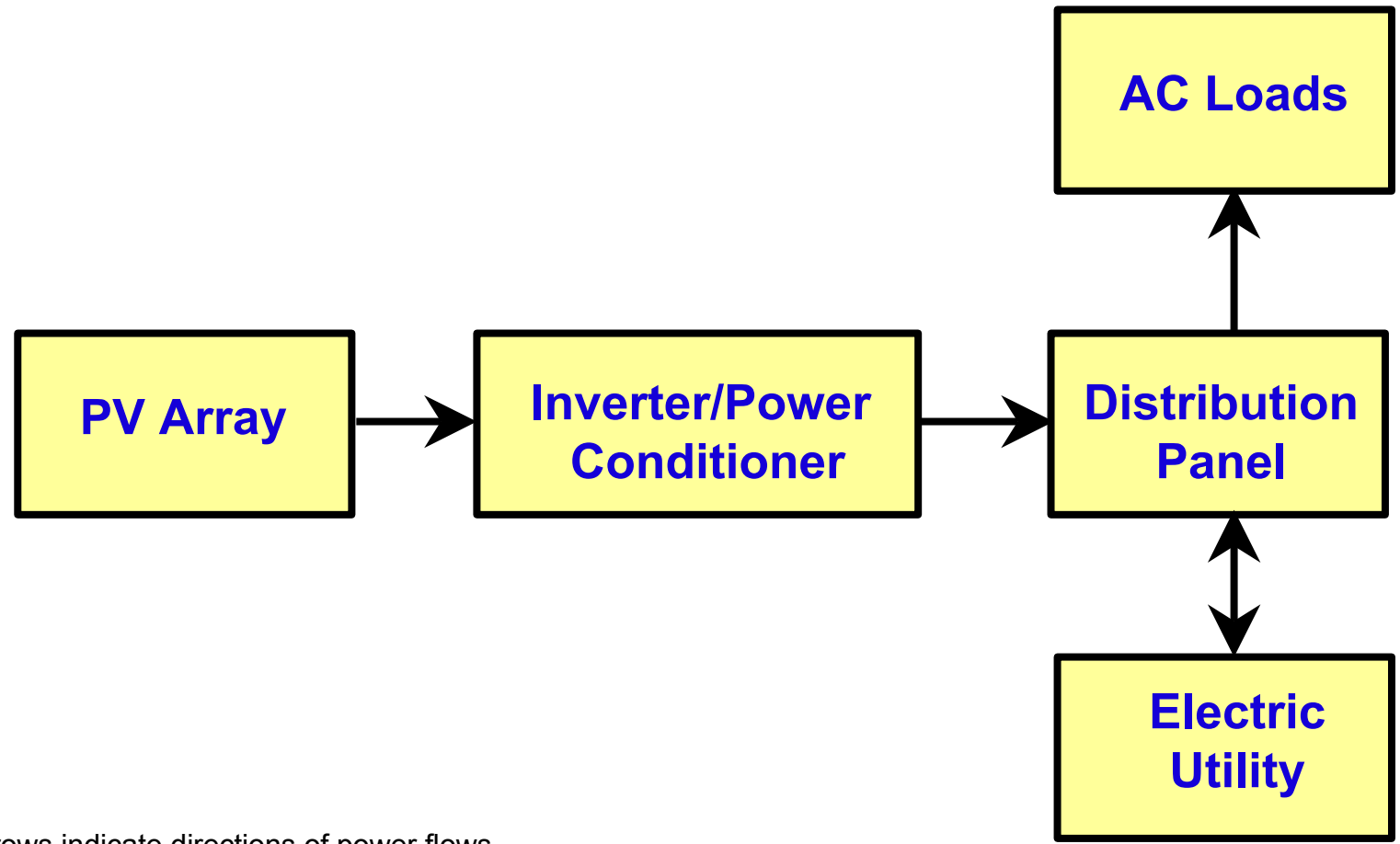
Solar Photovoltaic System: Advance Organizer



Types of Interactive Solar Photovoltaic Systems

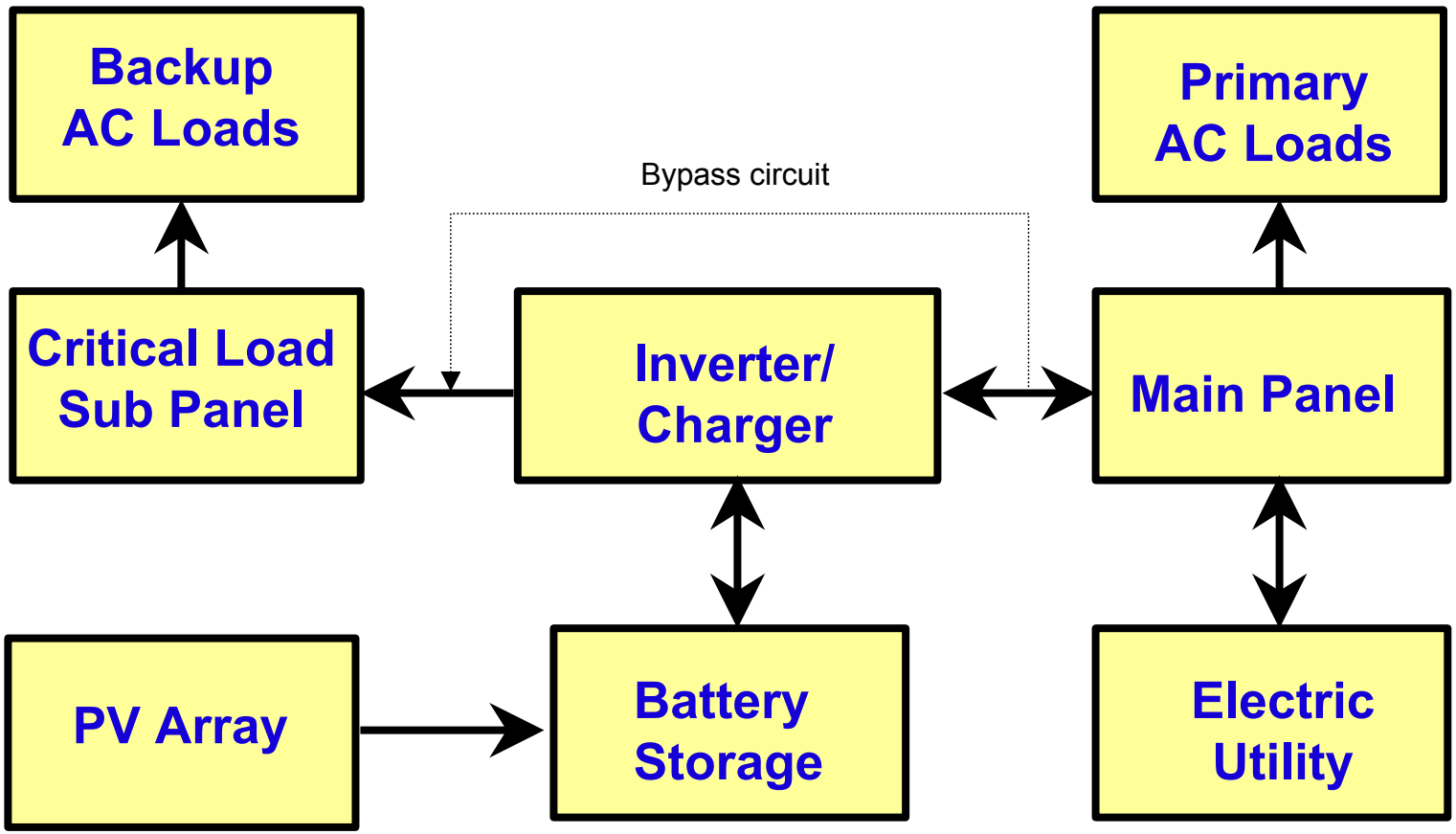
- **Simple Utility-Interactive**
  - PV system supplements on-site energy usage, electrical loads are supplied by either the PV system or utility or a combination of both, depending on the amount of PV generation and magnitude of the load.
  - PV array is directly connected to the inverter input, and inverter AC output is connected to the utility grid.
  - PV system operates in parallel and synchronously with the utility grid.
- **Utility Interactive with Battery Storage**
  - Can operate either in interactive or stand-alone mode, but not simultaneously.
  - PV, inverter and battery subsystems interface between the customer's main service panel and dedicated load subpanel.
  - In interconnected mode, excess PV energy not required for battery charging is inverted and supplements on-site loads or is sent back to utility.
  - When the grid de-energizes, inverter isolates from grid and powers load subpanel directly from batteries, similar to a UPS system.
  - Bypass switch allows load subpanel to be directly powered from grid, isolating the SPS.

Simple Utility-Interactive PV System (no energy storage)



* Arrows indicate directions of power flows

Utility-Interactive PV System with Battery Storage



* Arrows indicate directions of power flows

Solar Photovoltaic System Components

- **PV Array**
  - An electrical assembly of photovoltaic modules that convert sunlight to DC electricity.
- **Inverter**
  - A device that converts DC power from batteries or PV arrays into utility-grade AC power.
- **Energy Storage**
  - Electrical or other storage devices sometimes used to store energy produced by PV arrays for later consumption.
- **System Charge Control**
  - A device used to protect batteries from overcharge and overdischarge, sometimes provide load control functions.
- **Load**
  - Energy consuming electrical appliances served by the system.
- **Balance of System (BOS) Components**
  - Other equipment required to control, conduct, protect and distribute power in the system.

Photovoltaic Modules

- **Module (690.2)**
  - A complete, environmentally protected unit consisting of solar cells, optics, and other components, exclusive of tracker, designed to generate dc power when expose to sunlight.
  - Range in size from around 0.5 to over 3 m^2 surface area, with peak power output of 50 to 300 watts dc. Area power densities range from 80-120 W/m^2.
  - Most commercially available crystalline and multi-crystalline PV modules have 36 cells in series, and have open-circuit voltages of 20-22 volts dc, and can be connected in series up to 600 volts DC.
  - Some thin-film modules have open circuit voltages as high as 100 volts dc.

60-watt poly-crystalline module

75-watt crystalline module

Photovoltaic Arrays

- **Array (690.2)**
  - A mechanical integrated assembly of modules or panels with a support structure and foundation, tracker, and other components, as required, to form a direct-current power-producing unit.

Inverters for PV Systems

- **Inverter (690.2)**
  - Equipment that is used to change voltage level or waveform, or both, of electrical energy. Also known as a power processing unit (PCU) or power conversion system (PCS), and inverter is a device that changes dc input to ac output. Inverters may also function as battery chargers that use alternating current from another course and convert it into direct current for charging batteries.
  - Inverters for PV systems in sizes from 100 watts to custom designs of up to 1 MW or more
  - DC operating voltages of 12 volts up to 600 volts, with AC outputs from 120 V single phase to 480 V three phase.

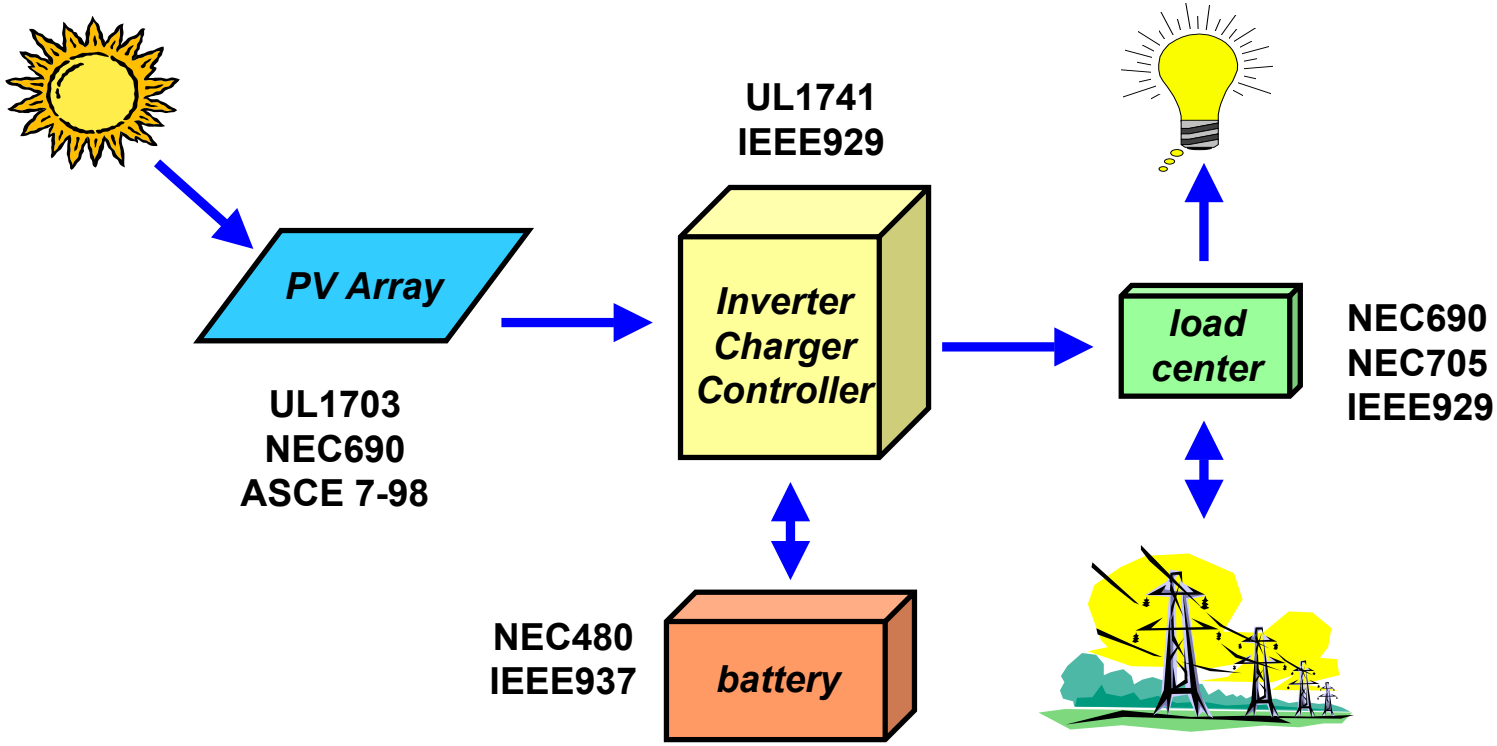
Batteries for PV Systems

- Batteries are used in some PV systems to *store energy* produced by the PV array and supply it to electrical loads as needed.
- Charge control is required in most cased to protect batteries from overcharge by PV array, and overdischarge from loads.

Principal Standards for Solar Photovoltaic Systems and Equipment

- **IEEE 929-2000 Recommended Practice for Utility Interface of Photovoltaic (PV) Systems**
  - IEEE P1547 Draft Standard for Distributed Resources Interconnected with Electric Power Systems (will apply to a broad range of interconnected distributed generation equipment)
- **UL Standard 1741 – Inverters, Converters, and Controllers for Use in Independent Power Systems**
  - Includes requirements of IEEE 929-2000
- **UL Standard 1703 – Flat-Plate Photovoltaic Modules and Panels**
- **National Electrical Code™**
  - Article 690 Solar Photovoltaic Systems
  - Article 705 Interconnected Electric Power Production Sources
  - Requires inverter UL1741 listing identified for interactive operation
- **Specifications – CSI Division 13 Section 13650 – Photovoltaic Collectors, Division 16 Section 16260 – Static Power Converters**
- **Local and state building codes**

Solar Photovoltaic System: Applicable Codes by Component



Electrical Code Compliance and Equipment Listing

- NEC requires approvals or listing for components and electrical hardware. Recognized laboratories include:
  - Underwriters Laboratory (UL) http://ulstandardsinfonet.ul.com
  - ETL Semko http://www.etlsemko.com
  - Canadian Standards Association (CSA) http://www.csa.ca
  - FM Global http://www.fmglobal.com
- Article 110-3(B): Examination, Identification, Installation, & Use of Equipment.
  - **(B) Installation & Use**. Listed or labeled equipment shall be used or installed in accordance with any instructions included in the listing or labeling.

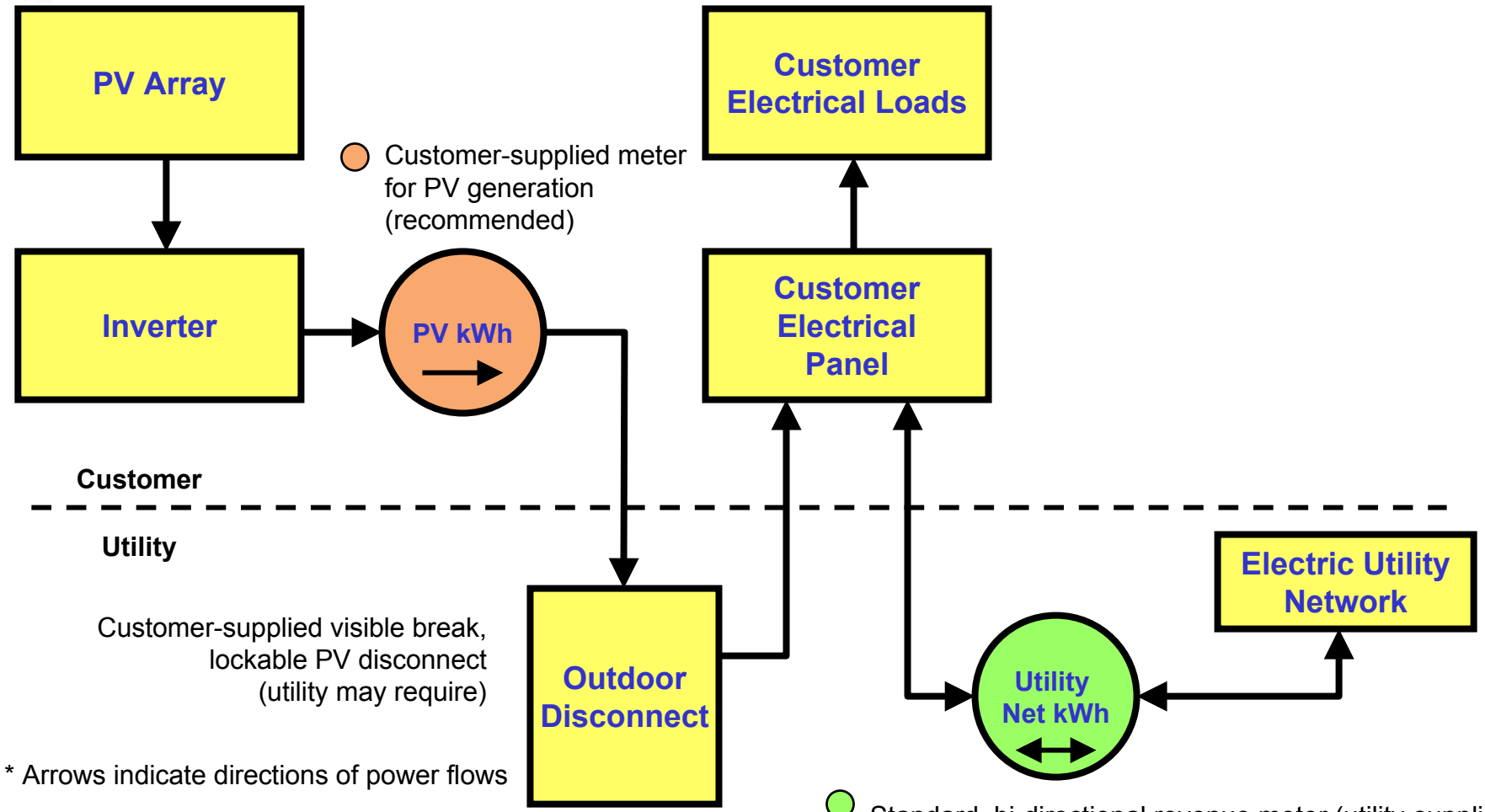
Utility Interconnection: Typical Issues

- Listed equipment
- Inspected and approved installations
- Liability insurance
- Disconnect provisions
- Metering options
- Billing practices
- Testing and monitoring
- Size restrictions
- Fees for interconnection application, special billing or metering

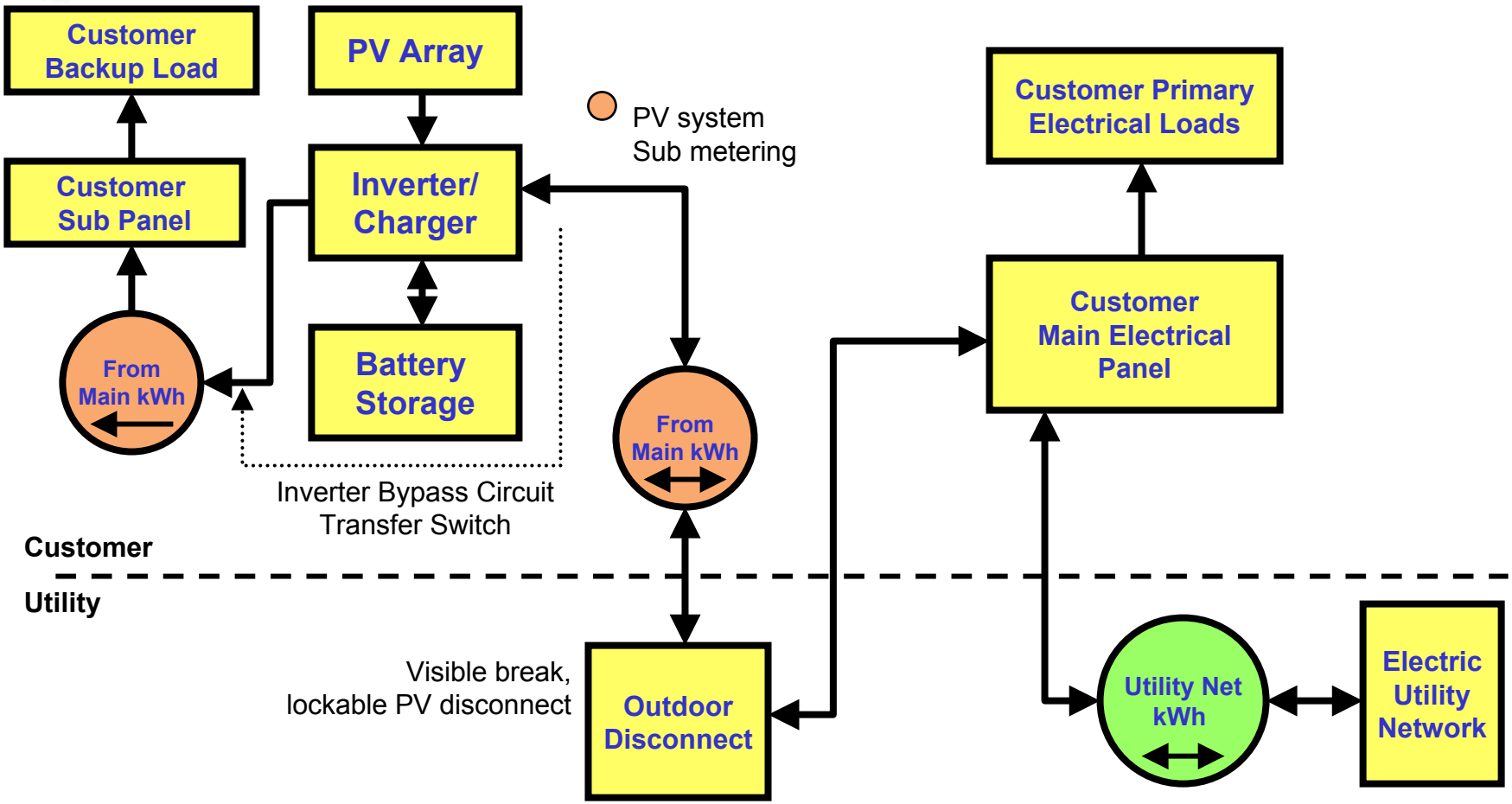
Utility Interconnection: Example by ComEd of Exelon

- Generating Capacity Under 25 kVA
  - Analysis performed
  - Accessible disconnect lockable with visible break
- Generating Capacity 25-50 kVA
  - Inspection by ComEd
- Generating Capacity >100 kVA
  - Rate 18
- Generating Capacity 50-2500 kVA
  - Protective Relays
- Generating Capacity 2500-10000 kVA
  - Voltage supervision
- Additional Requirements for Higher kVA

Utility-Interactive PV System
No Battery Storage – Net Metering



Utility-Interactive PV System with Battery Storage – Net Metering



Elements of a Quality and Code-Compliant PV System Installation

- System employs a well-engineered design and quality components;
- System and equipment are properly sized to meet expected or required performance;
- System uses listed, approved and appropriately rated equipment, and sunlight and weather resistant materials for outdoor application;
- PV array is mounted in an accessible, unshaded location with proper solar orientation, and uses roof penetrations and weather sealing methods consistent with accepted roofing industry standards;
- All equipment is properly labeled and safety hazards identified;
- Installation complies with all applicable building and electrical codes and accepted utility interconnection practice;
- System is inspected and approved by utility and code officials, owners/operators are trained on safety and operation.

Reference Resources

- Complete on-line resource for presentations, documents, reference and resource links:
  - http://www.fsec.ucf.edu/PVT/Education/training/inspgcps/handbook/index.htm
- Code and Standards for Photovoltaic Systems and Equipment:
  - http://www.fsec.ucf.edu/PVT/RESOURCES/pvcodes/index.htp
- Institute of Electrical and Electronics Engineers (IEEE) standards:
  - http://standards.ieee.org/
- Underwriters Laboratory standards:
  - http://ulstandardsinfonet.ul.com/
- National Electrical Code, NFPA 70, National Fire Protection Association:
  - http://www.nfpa.org

References (cont.)

- **Connecting to the Grid – Interstate Renewable Energy Association website:**
  - http://www.irecusa.org/connect/index.html
- **Florida Building Code**
  - http://www.floridabuilding.org/
- **Chicago Energy Conservation Code, 18-13**
  - http://www.ci.chi.il.us/Buildings/BuildingCode/EnergyCodeInfo.html
- **ASCE 7-98 Minimum Design Loads for Buildings and Other Structures**
  - http://www.asce.org/